PART TWO

Total Suspended Particulate Sampling for Metals

Chapter 7
Part Two - Total Suspended Particulate Sampling for Metals
Table of Contents

Page

1.0 Introduction 1
1.1 Sampling Overview 1

2.0 Facility Requirements 1
2.1 Filter Conditioning and Weighing Area 1
2.2 Calibration and Maintenance Area 2
2.3 Sampling Sites 2
2.4 Ancillary Equipment 2

3.0 Filter Preparation and Analysis 3
3.1 Inspection 3
3.2 Conditioning and Equilibration 3
3.3 Pre Sampling Weighing Procedure 4
3.4 Post Sampling Filter Handling 4
3.5 Post Sampling Weighing Procedure 4

4.0 Sampler Operation 4
4.1 Siting Requirements 4
4.2 Sampler Installation 5
4.3 Sampling Operations 5
4.3.1 Sampling Procedure 6

5.0 Calibration Procedures 7
5.1 Mass Flow Controlled TSP Calibration 8
5.1.1 Calibration Procedure 8

6.0 Determining TSP Concentrations 10

7.0 Performance Audit Procedures 11
7.1 Flow Rate Performance Audit Procedure for TSP Samplers 11
7.1.1 Audit Equipment 12
7.1.2 Audit Procedure 13
7.2 Audit Data Reporting 15
7.3 Audit Frequency 16
7.4 Systems Audit 16

8.0 Precision and Accuracy Assessment 16
8.1 Precision 16
8.2 Accuracy 17

9.0 Maintenance 17
9.1 Six Month Maintenance 18
9.2 As Needed Maintenance 18

10.0 Forms 18

FORMS

1. Example Orifice Certification – Range Factor Table 19
2. TSP Pre-Maintenance Audit and Calibration Form 20
3. TSP Audit Form 21

PHOTOS

1. Collocated TSP Samplers – Hammond, Indiana 11
2. Flow Rate Audit – Hammond CAAP Trailer 12

Part Two - Total Suspended Particulate Sampling for Metals

1.0 Introduction

On July 1, 1987, the U.S. Environmental Protection Agency (USEPA) promulgated new National Ambient Air Quality Standards (NAAQS) for Particulate Matter (PM). The new NAAQS changed the indicator for particles from Total Suspended Particulates (TSP) to PM_{10}, the latter referring to particles with a mean aerodynamic diameter less than or equal to 10 micrometers (µm). USEPA also revised the level and form of the primary standards by replacing the 24-hour TSP standard with a 24-hour PM_{10} standard of 50 $\mu g/m^3$, annual arithmetic mean. The secondary standard was revised by replacing it with 24-hour and annual standards identical in all respects to the primary standards.

Although the TSP NAAQS is no longer in effect, the TSP monitoring method has been retained for the collection of PM for metals analysis (primarily lead). Part 3 of Chapter 7 provides information and references for TSP sampling while Chapter 8 provides information and references for the metals analysis of TSP samples.

1.1 Sampling Overview

Particulate matter in the atmosphere that has an aerodynamic diameter in sizes of > 10 to 50 µm is referred to as Total Suspended Particulates (TSP). A high-volume sampler draws a known volume of ambient air at a constant flow rate through a covered housing. Particles are collected on a glass fiber filter during a specified 24-hour sampling period. A constituent of the TSP sample may be metals (i.e., lead) which may be quantified by laboratory analysis. The reference method for sampling is given in 40 CFR Part 50, Appendix L, CFR Part 50, Appendix B.

The following procedures are based on the use of a covered, high volume sampler using an electronically controlled mass flow control device (flow controller).

2.0 Facility Requirements

Facility requirements for TSP sampling for metals include a central laboratory that includes a filter conditioning and weighing area, a calibration and maintenance area, and individual field sampling stations. Facilities and equipment specific for metals analysis is listed in Chapter 8 of this manual.

2.1 Filter Conditioning and Weighing Area

Although TSP concentrations are no longer used for NAAQS compliance, TSP filters should be treated with the same care as PM_{10} or $PM_{2.5}$ filters. Therefore, the filter conditioning room should be large enough to accommodate filter processing, equilibration, weighing operations, and filter and record storage. The room should be equipped with the necessary air conditioning equipment to maintain an air temperature between 15 and 30 °C that is constant within ±3 °C and relative humidity less than 50 percent that is constant within ±5%. In addition, certified relative humidity and temperature measurement instruments must be maintained.

2.2 Calibration and Maintenance Area

A sufficiently large area should be designated as the calibration and maintenance test area. It should be equipped with the tools required for routine sampler maintenance (such as brush or motor replacement), orifice certifications, and ancillary equipment maintenance and repair.

2.3 Sampling Sites

All sampling locations must meet the guidelines set forth in 40 CFR Part 50 Appendix L, and Part 58 Appendix D as well as the siting guidelines outlined in Chapter 1, Section 4.0 of this manual. The following factors should also be considered when selecting a monitoring site:

- Samplers should be situated where the operator can access safely regardless of weather conditions. Sampler placement must consider routine operations such as calibration, sample pickup/setup, flow checks, and audits that involve transporting equipment and supplies to and from the monitoring site.
- Availability of adequate electricity to power sampler(s).
- Security of monitoring personnel and equipment. The security of personnel and the sampler itself depends largely on location. Rooftop sites with locked access and ground level sites with fenced compounds should be utilized whenever possible.

2.4 Ancillary Equipment

Listed below are equipment and supplies required for operation of a TSP sampling for metals network. Exact specifications for individual items can be found in the reference method described in 40 CFR Part 50, Appendix L and Appendix M.

- Analytical balance
- Relative humidity indicator
- Sampler:
  1. Aluminum shelter
  2. Motor
  3. Flow Controller
  4. Clock (6-day cycle with On/Off tabs)
  5. Elapsed timer meter
  6. Cone
  7. Filter cassette
- Certified flow rate transfer standard (Hansen orifice)
- Filters
- Certified Barometer (digital or aneroid)
- Manometer (water, oil or digital)

- Certified thermometer (digital or liquid)
- ANSI/ASTM Class 1, 1.1 or 2 mass reference standard weights
- Logbooks and database/laboratory and maintenance
- Filter data cards and envelopes
- Spare parts (i.e., motor brushes & armatures, gaskets)
- Extra/backup equipment (i.e., assembled motors, thermometer, barometer, flow controller)

3.0 Filter Preparation and Analysis

Outlined in 40 CFR Part 50, Appendix L and Appendix M are the acceptance criteria for filters used in TSP monitoring for metals.

Glass fiber filters are brittle and are easily broken. Care should be taken at all times to avoid damage or contamination.

An identification number is printed on each filter by the manufacturer. If filters are to be mailed to a laboratory for analysis, field personnel should be equipped with reinforced envelopes and manila folders for the protection of the exposed filters.

3.1 Inspection

All filters must be inspected for defects before use. An effective method to inspect filters for defects is with a light-box. A light-box uses a low wattage light bulb to illuminate a clear or translucent surface. Laying an 8” x 10” filter on this lighted surface aides in the inspection process. Defective filters should not be used for sampling. Some common defects are:

- pinholes
- loose material
- discoloration
- non-uniform appearance

3.2 Conditioning/Equilibration

Filters should be equilibrated in a controlled environment for at least 24-hours before initial weighing. The relative humidity of the equilibration room should be held in the range of 20 to 45 percent but should not vary more than ±5 percent of the mean value. Room temperature must be held constant within the range of 15 to 30 °C and not vary more than ±3 °C. Room conditions must be verified and recorded on equilibration days to ensure compliance of this guideline. Any system malfunctions (heating, air conditioning, etc.) and maintenance activities should be recorded in a laboratory logbook.

3.3 Pre Sampling Weighing Procedures

Filters should be weighed on an analytical balance with the same resolution and precision of the balance used for PM_{10} filter weighing. Refer to Chapter 7, Part 2, Section 3.3 for balance specifications and pre sampling procedures.

3.4 Post Sampling Filter Handling

Filters that are not to be analyzed immediately should be stored within a protective covering to prevent damage and the loss of particulate matter. A filter holder card provides adequate protection and provides a means to record important sampling information. See Form 5 in Part 2 of this chapter for an example of a filter holder & data card. Care should be used when removing the filter from the sampler. The glass fiber filters are brittle and easily damaged. Once the filter has been removed from the sampler, it may be folded along its long axis with the exposed side in and placed in the filter holder card. If any pieces of the filter are broken loose, place the pieces within the card. The holder card containing the folded filter can now be placed in an envelope for transport to the laboratory for analysis.

If filter cassettes are in use, the operator should elect to leave the “exposed” filter in the cassette for transport back to the laboratory. A cover on the cassette protects the filter from damage or loss of sample. Once returned to the laboratory, the exposed filter may be removed from the cassette and placed in the filter holder card.

3.5 Post Sampling Weighing Procedures

1. All filters must be equilibrated in a conditioning environment for at least 24-hours as described in Section 3.2 of this Part.

2. Repeat Steps 1 through 4 of the filter tare weighing procedure in Chapter 7, Part 2, Section 3.3.

4.0 Sampler Operation

Procedures in this section are intended as guidelines for use in a TSP monitoring for metals program that will accurately reflect trends in local or regional air quality. The effectiveness of the monitoring program depends largely on the responsible day-to-day operation of the monitoring site.

4.1 Siting Requirements

Detailed siting criteria are presented in 40 CFR Part 50, Appendix L, CFR Part 58, Appendix E and Chapter 1 of this manual. Some general site factors listed below:

- Samplers should be located farther than 20 meters from tree drip lines.
- Distances from a sampler to any obstacle (such as a building or a wall) must be twice the height that the obstacle protrudes above the sampler.
- Airflow must be unrestricted airflow 270° arc around the sampler inlet.
- Samplers should be located away from furnaces or incinerator flues.
- Spacing from roads and traffic must meet the requirements in 40 CFR Part 50, Appendix L, CFR Part 58, Appendix E.
- Sampler inlets must be a minimum of 2 meters from any collocated TSP sampler, or any other particulate sampler (i.e., PM_{10}, $PM_{2.5}$).

Samplers must be located where the operator can reach it safely despite adverse weather conditions. If the sampler is located on a rooftop, care must be taken that the operator's personal safety is not jeopardized by a slippery roof during rain and ice. Operation of the sampler, calibration, and routine maintenance can involve the transportation of supplies and equipment so safe access must be considered.

Adequate power must be available. Check the manufacturer's instruction manual for minimum voltage requirements.

4.2 Sampler Installation

1. Check the sampler for all components and proper operation before transport to the field monitoring site.

2. Samplers must be bolted down to a secure palette or mounting platform.

3. Check all power lines for cracks or cuts.

4. Plug the power cord into the line voltage. The use of a ground fault interrupter is recommended. Do not allow any electrical connection to become submerged.

5. Perform a flow rate calibration using the procedure in Section 5.0.

4.3 Sampling Operations

Most high volume samplers have been designed to accept filter cassettes. Loading cassettes in the laboratory or office reduces the risk of damage and contamination. Filters should be kept in protective folders or boxes prior to being loaded into the sample cassettes. Unexposed filters should never be folded or bent. The manufacturer stamps all filters with a unique identification number. See *Photo 3 PM_{10} Filter Cassettes and Filter Data Card* in Chapter 7, Part 2 for an example of the same type of filter cassettes used for TSP.

Each filter should be placed on the wire screen of the cassette centered with the numbered side down. Poorly aligned filters show an uneven white border after exposure. Do not over tighten the filter cassette because the gasket may stick to the filter causing filter loss and resulting in an invalid sample. Use protective covers over each sample cassette before transport to the monitoring site.

4.3.1 Sampling Procedures

Upon arrival at a monitoring site (initial sample setup, no previous sample):

1. Open the shelter roof and safely secure it. Most units have a latch on the rear of the shelter to prevent the lid from slamming down during sample setup and recovery.

2. Examine the cone's support screen. If it appears dirty or damaged, wipe clean or replace. Remove the protective cover from the filter cassette and position it in the center of the support screen. Tighten the thumbnuts sufficiently to hold the cassette securely and to seat the gaskets. Do not over tighten.

3. Lower the shelter roof and secure.

4. Turn on the sampler and allow the motor to come up to operating speed. Record or confirm the following information on a filter holder/data card:

   - Initial elapsed timer reading (normally the final reading from previous sample)
   - Site name and AIRS number (AQS site identification number)*
   - Sample run date *
   - Filter ID number *
   - Flow controller & motor serial numbers*
   - Sample set up date
   - Setup operator's initials
   - Initial flow indicator reading
   - Ambient pressure (mmHg) and ambient temperature (K)

   ** Information may be recorded prior to sample setup*

5. Observe the conditions around the monitoring site. Note any conditions that may affect filter particle loading such as fire, construction or demolition.

6. Turn off the sampler and ensure that the timer is "set" for the next sample run date and time.

As soon as possible after sampling has ended, the operator should return to the monitoring site and recover the exposed filter. Particle loss or filter damage may occur if the filter is left in the sampler for extended periods.

1. Turn on the sampler and allow the motor to come to operating speed.

2. Record the final elapsed timer reading and the final flow indicator reading.

3. Turn off the sampler.

4. Observe the conditions around the monitoring site. Note any conditions that may affect filter particle loading (fire, construction, demolition, etc.).

5. Raise the sampler roof and remove the filter cassette. Replace the protective cover.

6. Prepare the sampler for the next run as directed above.

5.0 Calibration Procedures

Calibration is defined as the relationship between an instrument's output and the output of a known reference standard. Two components of the TSP sampler that must be calibrated are: flow rate and sampling time (elapsed time meter).

The following equipment is necessary for proper calibration of the TSP sampler:

- NIST-certified traceable thermometer (liquid-alcohol filled or digital) capable of a measuring ambient air over a range of 0 to 50 °C to the nearest 0.1 °C.
- Aneroid or digital barometer capable of measuring barometric pressure over the range of 500 to 800 mmHg to the nearest millimeter of Hg and referenced at least annually to a standard of known accuracy with ±5 mmHg.
- Certified orifice transfer standard capable of measuring the operational flow rate of a high volume TSP sampler at standard conditions.
- Digital, water, or oil manometer with a range of at least 0 to 12 inches and 0.1 inch resolution.
- Standard time piece of known accuracy within ±2 min/24hr.
- Clean glass fiber filter as those used for monitoring.

Flow rate determination as described in this section is made using an orifice transfer standard that has been certified according to the procedure presented in Section 2.2.2 of the USEPA's "Quality Assurance Guidance Document 2.11" and Chapter 6 "Certification Methods of Transfer Standards" of this manual.

Consistency of temperature and barometric pressure units is required and will be expressed in Kelvin (°C + 273) and millimeters of mercury (mmHg).

Photo 1 in Chapter 7, Part 2 displays calibration and audit equipment described above.

5.1 Mass Flow Controlled TSP Calibration

The mass flow controlled sampler is designed to operate at a flow rate range of 1.1 to 1.7 m^3/min at actual (@ act) conditions. Since data must be reported at Standard Reference Conditions (@ SRC), the mass flow controller is calibrated @ SRC.

5.1.1 Calibration Procedure

1. Record the ambient temperature (T_a) and station pressure (P_a) on the calibration form.

   Place the thermometer out of direct sunlight. Ensure that the thermometer bulb or probe is not in contact with any surface. Allow the temperature reading to stabilize before taking the final reading. If the temperature reading has not fluctuated in two to four minutes, record the reading.

   If a digital thermometer is used, be sure the unit is in the correct measure scale (°C) and that it has sufficient battery power. Carry extra batteries.

2. If a liquid manometer is used for the calibration, check for leaks prior to placement in-line with the orifice.

   Check for leaks by blowing gently into the manometer tube. If a flow restriction occurs, then the water level will not flow freely. If the two valves at the top of the manometer are not open completely, a flow restriction may occur. A vapor lock can occur if liquid and air get trapped in the two valves. Once the tube is blown into, the water or oil level will elevate on one side and decline on the other. Place a fingertip over the end of the tube when the liquid has risen. If there is a leak, the liquid level will slowly drop. If there are no leaks, the liquid level will not change.

   If a digital manometer is used, be sure the unit is in the correct measure scale (mmHg), zero adjusted, and that it has sufficient battery power. Carry extra batteries.

3. Check the calibration orifice assembly for leaks.

   The calibration orifice assembly consists of an orifice, faceplate, and filter cassette with one clean glass fiber filter. A filter is necessary to provide adequate resistance to flow.

   Check the orifice to ensure that it is tightly seated (screwed on) onto the faceplate and that the faceplate gasket is in good condition.

4. Secure the orifice assembly to the sampler. Do not over tighten the nuts as that may result in damage to the faceplate or gasket.

5. Turn on the sampler and allow the motor to come up to operating speed (approximately 3 to 5 minutes).

Listen for whistling sounds that may indicate a leak in the system. Leaks are usually caused either by a damaged or missing gasket between the orifice transfer standard and the faceplate or by cross-threading of the orifice and the faceplate. Leaks will result in a lower flow rate while torn or improperly aligned filters will result in a higher flow rate.

6. While the sampler is warming up, determine the calibration set-point. The flow rate is adjusted to SRC by using the flow rate range for TSP of 1.1 to 1.7 m^3/min @ SRC. Normally the flow rate is set to 1.30 m^3/min @ SRC.

   Posted on the side of each orifice is certification data. This data consists of a table of true flow rate values with corresponding low and high range factor data. For a true flow rate of 1.30 m^3/min, find and record the Low and High Range Factor.

   Use following formulas to calculate the desired manometer reading for the flow rate set point:

$$\text{Average Range Factor} = \frac{\text{Low Range Factor} + \text{High Range Factor}}{2}$$

$$\text{Desired Manometer Reading (inches of water)} = \text{Average Range Factor} * \frac{T_a}{P_a}$$

   Where:

Range factor	=	orifice certification data corresponding to orifice flow rate
T_a	=	ambient temperature, K
P_a	=	barometric pressure, mmHg

   Example calculation:

   Refer to Form 1 Example Orifice Certification – Range Factor Table

   Where:

True Flow of 1.30,	Low Range Factor	=	16.761 and
	High Range Factor	=	17.015
	T_a	=	20 °C = 293 K
	P_a	=	740.0 mmHg

$$\text{Average Range Factor} = \frac{16.761 + 17.015}{2} = 16.888$$

$$\text{desired manometer reading (inches of water)} = 16.888 * \frac{293}{740} = 6.69$$

Given the above ambient conditions and the example orifice certification data, the operator must adjust the flow controller (set point) so that the manometer reads 6.69 inches.

7. Adjust sampler flow controller until the motor is producing a stable flow at the manometer set point as determined above.

   After each flow controller adjustment, allow one to three minutes for the flow to stabilize before making further adjustments. After the final adjustment, turn off the sampler then turn on again to see if the sampler will duplicate the set flow rate. If the operator is unable to achieve a stable flow, the flow controller, motor, or both may need to be replaced.

6.0 Determining TSP Concentrations

Measurements of TSP concentrations in the ambient air were used to determine attainment status of the National Ambient Air Quality Standards for TSP. Since this standard has been replaced with a PM_{10} standard, the following calculations are presented for informational purposes only.

To calculate the concentration of any given TSP sample, the following formula is used where:

$$\text{TSP Concentration, } \mu g/m^3 = 10^6 * \frac{(W_g - W_t)}{V_a}$$

W_g = gross filter weight (after sampling)
W_t = tare filter weight
V_a = total sample volume in units, m^3/min

Total volume = total sample time in minutes * average flow rate, m^3/min @ SRC

Photo 1
Collocated TSP Samplers
Hammond, Indiana

7.0 Performance Audit Procedures

The primary goal of an auditing program is to identify problems that may result in suspect or invalid data. Performance audits should be conducted under the following guidelines:

- Audits must be performed without special preparation or adjustments made to the system.
- The individual performing the audit must be someone other than the routine operator and have a thorough knowledge of all instruments or processes being evaluated.
- All aspects of the audit must be completely documented including the types of instruments and transfer standards, model and serial numbers, calibration information, etc.
- It is recommended that performance audits be done with the operator in attendance.

7.1 Flow Rate Performance Audit Procedure for TSP Samplers

For this procedure, the following is assumed:

- The TSP sampler uses an electronic mass flow controller for flow rate control.
- The sampler has been calibrated to operate at a flow rate of approximately 1.30 m^3/min @ SRC.

- The orifice transfer standard has been certified by the Indiana Department of Environmental Management's Quality Assurance Laboratory @ SRC.

7.1.1 Audit Equipment

The following equipment is required on site (See Photo 6 in Chapter 7, Part 2):

- An audit orifice flow transfer standard and its associated certification data (slope, intercept, and range factor table). This orifice must be different from one used for calibrations or QC flow checks.
- A digital or water manometer with a 0 to 16 inch range and a resolution of 0.1 inch.
- A digital or liquid thermometer capable of measuring ambient air temperatures over the range of 0 to 50 °C and a resolution of 0.1 °C. The thermometer should be NIST traceable or an ASTM thermometer.
- An aneroid or digital barometer capable of measuring ambient pressure over the range of 500 to 800 mmHg with a resolution of one mmHg.
- Field Data Sheet or laptop computer with the OAMD (see Section Chapter 7, Part 2, Section 10).

Photo 2
Flow Rate Audit
Hammond CAAP Trailer

7.1.2 Audit Procedure

1. Measure and record the ambient temperature (T_a) and barometric pressure (P_a) on the audit form.

   Place the thermometer out of direct sunlight. Ensure that the thermometer bulb or probe is not in contact with any surface. Allow the temperature reading to stabilize before taking the final reading. If the temperature reading has not fluctuated in two to four minutes, record the reading.

   If a digital thermometer is used, be sure the unit is in the correct measure scale (°C) and that it has sufficient battery power. Carry extra batteries.

2. Record on the audit form the observed flow @ SRC (calibration set point) from the last calibration.

   This data is obtained from the calibration form which may be posted inside the sampler shelter or may be obtained from the OAMD.

3. If present, remove the sample cassette, cover and store it in a location where it will not be damaged.

4. If a liquid manometer is used for the audit, check for leaks prior to placement in-line with the orifice.

   Check for leaks by blowing gently into the manometer tube. If a flow restriction occurs then the water level will not flow freely. If the two valves at the top of the manometer are not open completely, a flow restriction may occur. A vapor lock can occur if liquid and air get trapped in the two valves. Once the tube is blown into, the water or oil level will elevate on one side and decline on the other. Place a fingertip over the end of the tube when the liquid has risen. If there is a leak, the liquid level will slowly drop. If there are no leaks, the liquid level will not change.

   If a digital manometer is used, be sure the unit is in the correct measure scale (mmHg), adjusted to zero and that it has sufficient battery power. Carry extra batteries

5. Check the audit orifice assembly for leaks.

   The orifice assembly consists of an orifice, faceplate and filter cassette with one clean quartz filter. A filter is necessary to provide adequate resistance to flow.

   Check the orifice to ensure that it is tightly seated (screwed on) onto the faceplate and that the faceplate gasket is in good condition.

6. Install the orifice assembly on the sampler.

Check that the gaskets are in good condition. Tighten the faceplate nuts evenly on alternate corners to seat the gaskets. Do not over tighten. When using an audit filter do not use resistance plates with the orifice.

7. Turn on the sampler and allow it to warm up (3 to 5 minutes).

8. Ensure that the following is recorded on the audit form:

- Site name, AQS #, audit date
- Flow controller and motor serial numbers
- Audit ambient temperature (T_a) in K (°C = 273)
- Audit barometric pressure (P_a), mmHg
- Calibration observed flow @ SRC (calibration set point)
- Audit orifice transfer standard S/N and calibration information
- Unusual conditions (construction, weather, etc)

9. From the manometer, determine pressure drop across the orifice and record as ΔH_2O on the audit form.

10. Read the indicated flow from the meter in the flow controller electronics box.

11. Calculate the audit flow rate (True Flow @ SRC) through the orifice using the following formula:

$$\text{Orifice Range Factor} = \frac{\Delta H_2O * P_a}{T_a}$$

Where:

T_a = audit temperature, K
P_a = audit barometric pressure, mmHg
True Flow @ SRC is obtained from the audit orifice certification Range Factor table. This table is posted on the side of the audit orifice.

Example calculation:

Where:

T_a = 22 °C = 295 K
P_a = 745.0 mmHg
ΔH_2O = 6.2 inches
Example Orifice Certification Range Factor Table (Form 1)

$$\text{Orifice Range Factor} = \frac{6.2 * 745}{295} = 15.658$$

From the Example Orifice Certification Range Factor Table, 15.658 is between the range of low 15.514 and high 15.759. In the table this corresponds to a True Flow @ SRC of 1.25 m^3/min.

12. Calculate the % difference between the sampler's True Flow @ SRC (Q_{True}) and the sampler's observed flow rate @ SRC ($Q_{Observed}$ from the last calibration).

$$\% \text{ difference} = \frac{Q_{Observed} - Q_{True}}{Q_{True}} * 100$$

Where:

Q_{True} = True flow rate @ SRC, m^3/min
$Q_{Observed}$ = Observed flow rate @ SRC (flow set at calibration), m^3/min

Example calculation:

Where:

Q_{True} = 1.25 m^3/min
$Q_{Observed}$ = 1.30 m^3/min

$$\% \text{ difference} = \frac{1.30 - 1.25}{1.25} * 100 = 4.0\%$$

Audit results (flow rate % difference) produce three possible outcomes and actions:

% Difference	Condition / Data Status	Action
< ±5.0%.	Passed Audit / Data Valid	No action is necessary
> ±5.0% and ≤ ±7.0%	Passed Audit / Data Valid	Calibrate sampler to avoid future data loss
> ±7.0%	Failed Audit / Data Invalid	Calibrate sampler. Data invalid from failed audit until sampler is re-calibrated.

7.2 Audit Data Reporting

Audit results should be reported to appropriate personnel as soon as possible after audit completion and data entered into OAMD. A paper copy of the audit may be forwarded to the operator or personnel may view the audit in the database. If data is invalid (≥ ±7.0 percent difference), the auditor should promptly inform the operator verbally and in written form (memo or e-mail).

A standard piece of field equipment for IDEM-OAQ-QAS staff is a cell phone. Immediate notification of results while the auditor is still on-site is now possible. If audit results are ≥ ±7.0% difference the auditor while at the site should:

- Call the operator with the audit results and request instructions. The operator may ask the auditor not to take any action or to proceed with the next step.
- The auditor may perform a “temporary” calibration of the sampler with the audit device. This calibration will minimize data loss and is in effect until the operator can reach the site to perform any maintenance, equipment replacement, and perform a “permanent” calibration.

If the operator cannot be reached, the IDEM-OAQ-QAS policy is to perform a “temporary” calibration until the operator can perform the “permanent” calibration. A “permanent” calibration by the operator is important so that the independence rule for accuracy audits is maintained (see Section 8.2, Accuracy, of this Part).

7.3 Audit Frequency

The USEPA requires that SLAMS monitoring networks audit at least 25 percent of the samplers each quarter thereby auditing each sampler in the network once per year.

The Indiana Department of Environmental Management conducts audits of all TSP samplers in its monitoring network at least once each month to ensure minimal data loss.

7.4 Systems Audits

System audits are an on-site inspection and review of the total monitoring process from initial filter preparation and sampling to final analysis and data reporting. System reviews are generally done at the initial setup of a network then on an annual or on an as needed basis. The specific guidelines and procedures for this type of audit are found in Chapter 15 of this manual, System Audit Criteria & Procedures for Evaluating Ambient Air Monitoring Networks.

8.0 Precision and Accuracy Assessment

8.1 Precision

Precision of the TSP monitoring for metals network is measured by the use of duplicate or collocated samplers (See Photo 1 in this Part). Each set of duplicate samplers must be located between 2 to 4 meters from each other. One of the samplers in the set is designated as the reporting sampler and data from this sampler is used to report air quality. The second sampler is designated as the collocated sampler and data from this sampler is used to calculate network precision. Calibration, sampling frequency and duration, and analysis must be conducted in the same manner for each sampler. The percentage differences between the lead concentrations ($\mu g/m^3$) from the two samplers are used to determine precision. The calculations are described in detail in 40 CFR Part 50, Appendix L and CRF Part 50, Appendix A.

The minimum required number of collocated sites is based on the total number of sites in the reporting agency network:

- 1-5 sites, 1 collocated site
- 6-20 sites, 2 collocated sites
- > 20 sites, 3 collocated sites

Precision estimations may be improved by installing additional collocated samplers. To further improve the representativeness of the precision data, reporting agencies should select collocated sites that have the highest annual mean concentrations.

8.2 Accuracy

The accuracy of the TSP monitoring for metals network is measured by auditing the flow rate performance of the samplers in the network. The percentage difference between the audit flow rate and the sampler flow rate is used to determine accuracy. The calculations are described in detail in 40 CFR Part 50, Appendix L, CFR Part 50, Appendix A.

The USEPA requires that 25 percent of the samplers within a reporting organization's network be audited for accuracy each quarter. To improve accuracy estimates, additional accuracy flow rate audits may be conducted each calendar quarter. For example, the IDEM-OAQ-QAS audits all TSP samplers in its monitoring network at least once each quarter. This audit frequency provides additional accuracy flow rate data and also ensures minimal data loss due to "out-of-calibration" conditions.

9.0 Maintenance

Routine preventive maintenance helps prevent failures of the monitoring and analytical processes. The overall objective is to increase measurement reliability and prevent data loss. The guidelines below are intended to be general routine maintenance procedures. More detailed information can be found in the manufacturer's instruction manual for individual instruments.

Maintenance records must be kept for each sampler or instrument. These records should contain a history of the sampler, including all replacement parts, suppliers, costs, installation dates, etc.

9.1 Six Month and One Year Maintenance

1. Replace Motor Brushes. Follow manufacturer's instructions for the replacement of motor brushes. Replacement frequencies will vary depending on total operating hours of each motor. Generally brush motors should be replaced at least annually.

   A flow controller calibration must be performed after any motor maintenance or motor replacement.

2. Clean the flow controller probe with alcohol and properly align the probe in the throat of the sampler's cone.

9.2 As Needed Maintenance

1. Gaskets should be checked at each setup and replaced if they are worn, cracked, or excessively flat.

2. The inside of the shelter should be routinely cleaned.

3. Motor armatures should be checked during brush change and replaced as necessary.

10.0 Forms

Calibration and audit forms used with TSP monitoring for metals are similar to those used with the PM_{10} monitoring program. Refer to Chapter 7, Part 2, Section 10 for examples of these forms. Also, audit and calibration calculation formulas are similar with the major difference of the design flow rate. The PM_{10} design or normal flow rate is 1.13 m^3/min and the TSP design or normal flow rate is 1.30 m^3/min.

Form 1
Example Orifice Certification – Range Factor Table

Indiana Department of Environmental Management
Office of Air Quality – Hi-Volume Orifice Certification

Agency	Cert Date	
STATE QA	23-FEB-2004	
Orifice SN	**Slope**	**Intercept**
10019	1.9431329	0.0472172

Recertification is Due: 23-FEB-2005

Flow Rates are corrected to Standard Reference Conditions of 298 K and 760 mmHg.

Range Factor = [Manometer Reading * Station Baro Press (mmHg)] / Site Temp (K)

Use the following formulas to directly calculate the true flow:

CM=SQRT[MR*(BP/760) * (298/Temp)]

True Flow = (1/Slope) * (CM – Intercept)

Where:

CM = Corrected Manometer Reading

MR = Manometer in inches of water

BP = Barometric Pressure in mmHg

Temp = Ambient Temp in K (C+273)

True Flow	Range Factor		True Flow	Range Factor		True Flow	Range Factor	
(m^3/min)	Low	High	(m^3/min)	Low	High	(m^3/min)	Low	High
0.90	8.138	8.315	1.14	12.942	13.165	1.38	18.855	19.125
0.91	8.316	8.495	1.15	13.166	13.391	1.39	19.126	19.397
0.92	8.496	8.677	1.16	13.392	13.619	1.40	19.398	19.671
0.93	8.678	8.861	1.17	13.620	13.849	1.41	19.672	19.948
0.94	8.862	9.046	1.18	13.850	14.081	1.42	19.949	20.226
0.95	9.047	9.234	1.19	14.082	14.315	1.43	20.227	20.506
0.96	9.235	9.424	1.20	14.316	14.551	1.44	20.507	20.788
0.97	9.425	9.615	1.21	14.552	14.789	1.45	20.789	21.072
0.98	9.616	9.809	1.22	14.790	15.028	1.46	21.073	21.358
0.99	9.810	10.004	1.23	15.029	15.270	1.47	21.359	21.645
1.00	10.005	10.201	1.24	15.271	15.513	1.48	21.646	21.935
1.01	10.202	10.400	1.25	15.514	15.759	1.49	21.936	22.227
1.02	10.401	10.601	1.26	15.760	16.006	1.50	22.228	22.520
1.03	10.602	10.805	1.27	16.007	16.255	1.51	22.521	22.816
1.04	10.806	11.009	1.28	16.256	16.507	1.52	22.817	23.113
1.05	11.010	11.216	1.29	16.508	16.760	1.53	23.114	23.413
1.06	11.217	11.425	**1.30**	16.761	17.015	1.54	23.414	23.714
1.07	11.426	11.636	1.31	17.016	17.272	1.55	23.715	24.017
1.08	11.637	11.849	1.32	17.273	17.531	1.56	24.018	24.322
1.09	11.850	12.063	1.33	17.532	17.792	1.57	24.323	24.629
1.10	12.064	12.280	1.34	17.793	18.054	1.58	24.630	24.938
1.11	12.281	12.498	1.35	18.055	18.319	1.59	24.939	25.249
1.12	12.499	12.719	1.36	18.320	18.586	1.60	25.250	25.562
1.13	12.720	12.941	1.37	18.587	18.854	1.61	25.563	25.877

Form 2
TSP Pre-Maintenance Audit and Calibration Form

TSP Pre-Maintenance Audit and Calibration Form			
County:		City:	
Site:		AQS #:	
Date:		Initials:	
Ambient Temperature:		K (°C +273):	
Ambient Pressure:	mmHg		

Sampler Information

Orifice SN:		Orifice Cert Date:	
Current Flow Controller SN:		Flow Controller Cal. Date:	
Current Motor #:		Motor Change Date:	
New Motor #:		New Flow Controller SN:	

Formulas

Range Factor (orifice) = ambient pressure * manometer reading, inches H_2O / ambient temperature, K

% Difference = (observed flow – true flow) / true flow * 100

Pre-Maintenance Audit:

$$\text{Range Factor} = \frac{\text{amb press * inches } H_2O}{\text{ambient temp in K}}$$

True Flow (SRC) = from orifice Range Factor table

Obtain Observed Flow @ SRC from previous cal. sheet from the Calibration row and the True Flow @ SRC column.

Calibration:

$$\text{Observed Flow @SRC} = 1.30 * \frac{\text{(ambient pressure, mmHg * 298)}}{\text{(760 * ambient temperature in K)}}$$

$$\text{Manometer Reading, inches } H_2O = \frac{\text{(average range factor * ambient temp in K)}}{\text{ambient pressure, mmHg}}$$

** Find avg. range factor for Observed Flow @ SRC set point and plug into above formula **

Orifice SN	Inches H_2O 1 dec. place	Range Factor inches H_2O * BP/ Temp (K) 3 dec. places	Observed Flow @SRC 2 dec. places	True Flow @SCR 2 dec. places	% Diff	Flow Controller Meter Reading
Pre-Main Audit						
Calibration						

** If an audit could not be performed, please indicate reason in the comments section **

Comments: ____

Form 3
TSP Audit Form

Indiana Department of Environmental Management
Office of Air Quality
Quality Assurance Section

PM_{10} / TSP Audit

Site: ____________________ Audit Date: ____________

AQS #: **18-** ____________________ Performed by: ____________

Sampler Information

Flow Controller SN: ____________ Calibration Date: ____________

Calibration Temp °C/K: ______ °C / ______ K Calibration BP (mmHg): ____________

Audit Information

Audit Orifice SN: ____________ Orifice Cert Date: ____________

T_a - Audit Temp °C/K: ______ °C / ______ K P_a - Audit BP (mmHg): ____________

Δ P-Manometer (" H_2O): ____________ Range Factor: ____________

Flow Controller Meter: ____________ Std Flow @SRC (m^3/min): ____________

Observed Flow @SRC (m^3/min): ____________

% Difference: ____________

Formulas

Range Factor = $\Delta P * P_a / T_a$

TSP Observed Flow @SRC = 1.30 @ act * [(Cal BP *298) / (Cal Temp * 760)]

PM_{10} Observed Flow @SRC = 1.13 @ act * [(Cal BP *298) / (Cal Temp * 760)]

% Difference = (Observed Flow – Std Flow) / Std Flow * 100

Site Inspection and Remarks

ETM working properly: ______ Remarks:

Clock working properly (day & time): ______

General condition of site & shelter: ______